# SATELLITE PICTURES AND THE ORIGIN OF HURRICANE ANNA

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## ABSTRACT

Satellite pictures used in conjunction with conventional data indicate that the cyclonic circulation that developed into hurricane Anna of 1961 existed a day or more before it was detected with conventional data alone. It is interesting to speculate if the "area of origin" of many Atlantic hurricanes will be pushed farther eastward as more satellite data become available.

## 1. THE ORIGIN OF HURRICANE ANNA

There are good preliminary indications that hurricane Anna (1961) developed from a low pressure area originally located over Africa; this was also true of hurricanes Debbie and Esther [1], but the conventional synoptic analyses to support this view, supplemented by TIROS III satellite cloud pictures, will be published at a later time. Anna [2] reached hurricane force on July 20. But in this short note we shall discuss only some early stages of the disturbance, and indicate that a prominent circulation became evident from TIROS cloud patterns between July 16 and July 17. By July 17 a tropical cyclone [1] existed near 12° N., 43° W.; a weaker cyclonic circulation may have existed even earlier.

On July 16, the cloud mass from which Anna developed was located near 10° N., 39° W., and occupied an area of 3° of longitude by 4° of latitude. This cloud is shown in figure 1, which is a mosaic of pictures taken by TIROS III during one orbital pass as the satellite moved over the Atlantic Ocean from northwest to southeast. Some of the main cloud features have been sketched near their correct [2] geographical position within the dark gray area which outlines the region photographed by TIROS during this pass. Although there may be some organization present in the cloud patterns between latitudes 10° N. and 20° N., the organization, if any, is weak.

However, by 1449 GMT on July 17, a marked change had occurred. The main cloud had moved to about 12° N., 43° W. as shown in figure 2a; another part of the bright, relatively uniform, cloud was centered near 9° N., 44° W. And, by contrast with figure 1, a pronounced organization of cloud lines, curving sharply into the overcast [3] area from the east and north, is now evident. This is seen more clearly in the single frame, figure 2b, extracted from figure 2a. It is known that the direction of cloud lines is usually related to the vector of the vertical shear of the wind [3, 4, 5, 6]; and when the shear vector lies along the wind, as it often does in the tropical Atlantic at low levels, the cloud lines are also related to the wind direction. Much of the time, these lines are close in direction to the low-level wind. Thus, the curved, "spiral" cloud array in figure 2 indicates that the vertical wind shear vectors were arranged in a curved pattern, and that probably the wind was curved cyclonically. Moreover, the marked change in pattern occurred between the times of figures 1 and 2, i.e., between about 1520 GMT, July 16, and 1440 GMT, July 17, 1961.

As usual, on July 17, there were not many ship reports in the area where the spiral cloud array occurred. The available reports are shown in figure 3. The ship reports and cloud pictures were used to produce streamline analyses for a series of days. The analysis shown in figure 3 is for 1200 GMT on July 17. The report of a west wind at 1800 GMT near 10° N., 46° W. supports the existence of a closed circulation in the spiral cloud area. This cyclone reached hurricane force on July 20 and was then named hurricane Anna [7, 8].

However, Dunn, and Staff ([2], p. 110) suggest that Anna originated from a region of radar echoes sighted by a Navy reconnaissance plane [8]. The storm was assumed to have developed to the east of the Windward Islands in an area associated with these radar echoes. The satellite cloud pictures do not support that assumption. To see what did happen, let us examine the cloud information available on July 17 to the west of the tropical cyclone of figure 3.

Figure 4 shows a picture, with a latitude-longitude grid superposed, taken at 1629 GMT, July 17, i.e., about 100 min. after the spiral cloud of figure 2 was photographed. Figure 4 shows some rather bright clouds arranged from the South American coast at longitude 64° W., north-

[1] The term "tropical cyclone" implies nothing about intensity; see *Glossary of Meteorology*, American Meteorological Society, 1959, p. 593.

[2] The locations shown in the gray areas are nearly correct. More precise locations, from latitude-longitude overlays, were used in preparing this article.

[3] The top of the overcast cloud is at high levels as shown by infrared radiation measurements from the satellite. The more broken, cumuliform cloud patterns near the top of figure 2b probably represent stratocumulus and cumulus cloud fields.

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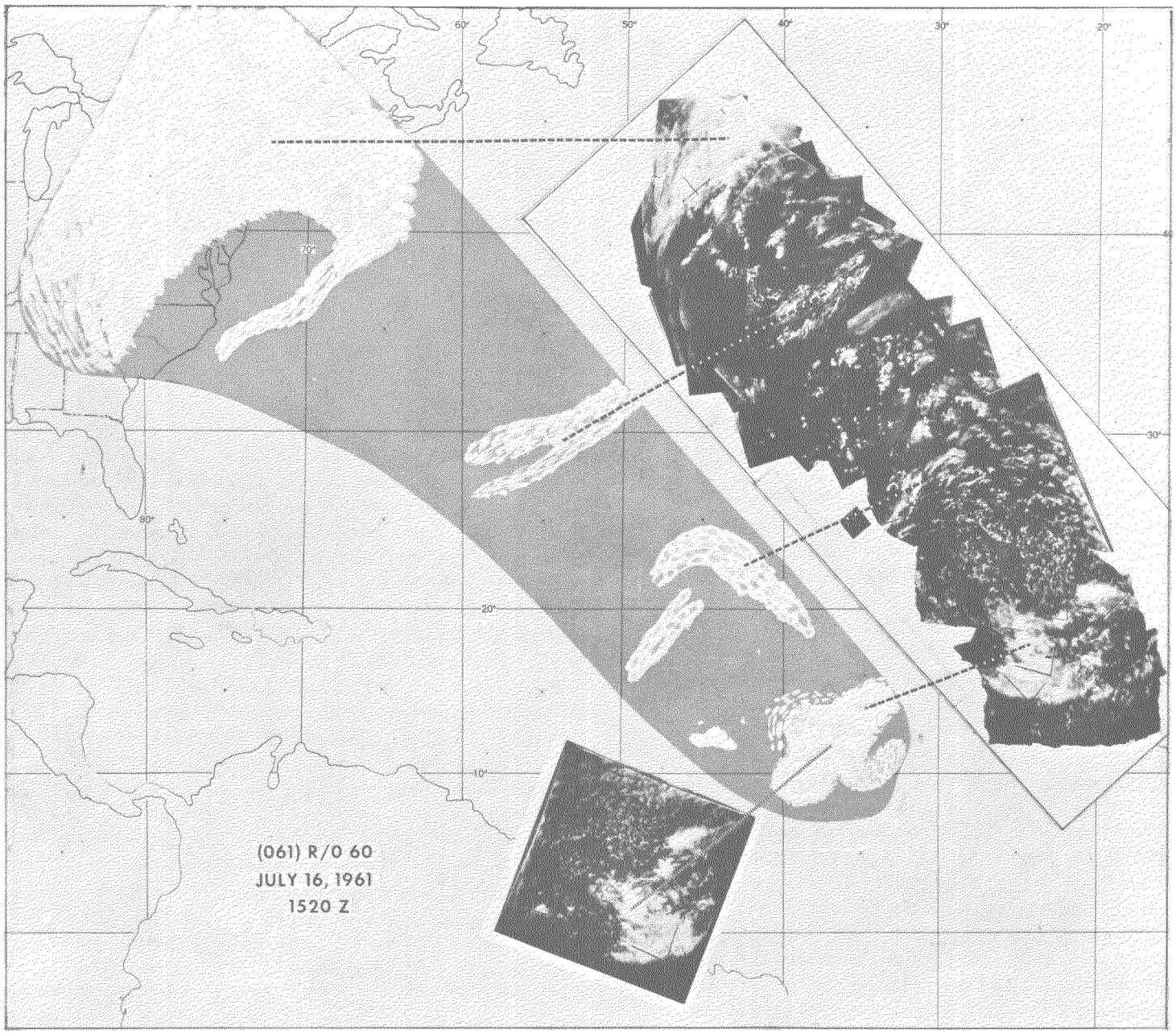
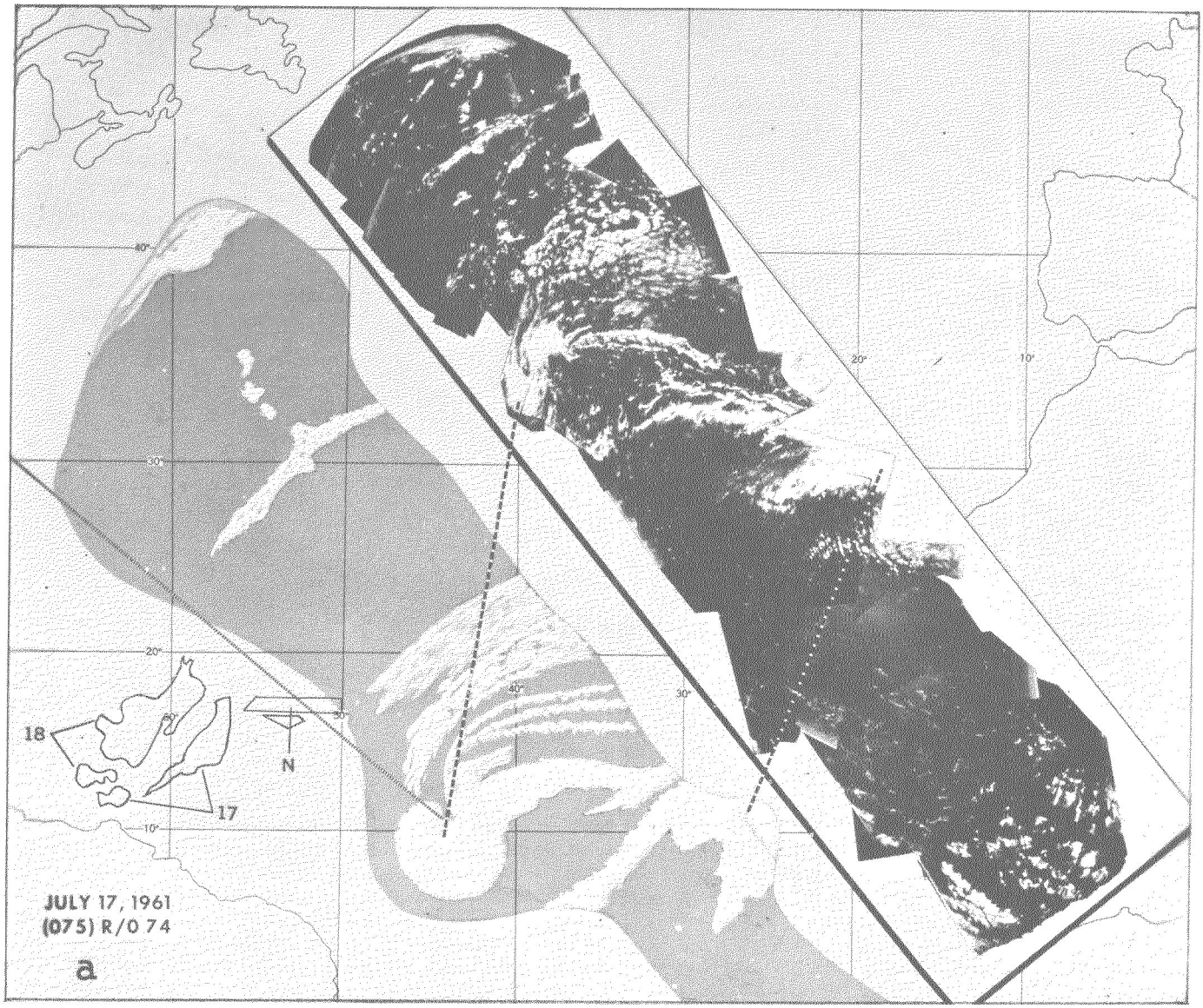



FIGURE 1.—A composite of TIROS III pictures taken at about 1520 GMT, July 16, 1961. The dark-gray area is the geographic area covered by the TIROS photographs. The cloud mass from which hurricane Anna later formed is located near 10° N., 39° W.

eastward to 15° N., 57° W. The area of this bright cloud array has been sketched on figure 2a. The Navy reconnaissance plane, some of whose positions are indicated on figure 3, reported strong radar echoes from the area near 16° N., 54° W., and this echo area is also sketched on figure 2a. That this "echo" area was separated from the tropical cyclone is evident in at least two ways. The Navy plane did not report echoes from positions 11, 12, and 13. Actually, at positions 11, 13, and 14, it reported partly cloudy "present weather," although at position 12 it reported a continuous layer of clouds. Moreover, when we examine the satellite pictures on July 18 (fig. 5) we note that the cloud associated with the tropical cyclone[4] had moved farther west to about 12° N., 50° W. and was indeed separated from a cloud mass centered near 16° N., 61° W. The separate cloud mass (fig. 5, July 18) lay mainly between latitudes 14° N. and 18° N. and was located about 3° west of the cloud in figure 4 (July 17); this cloud area for July 18 has also been outlined in figure 2a. Thus, two separated cloud masses existed also on July 17.

[4] The cloud streets evident on July 17 are not evident on July 18 because they have apparently been compressed near the picture horizon in fig. 5 (top mosaic).



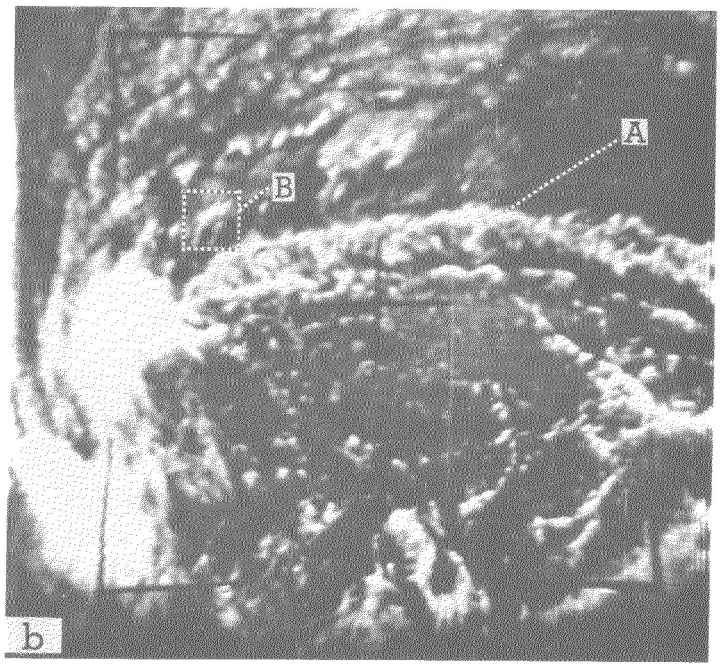




FIGURE 2.—(a) A composite of TIROS III pictures taken at about 1440 GMT, July 17, 1961. The main cloud mass located near 12° N., 43° W. is the cloud which appears in figure 1 and later developed into hurricane Anna. Another bright cloud mass is located about 15° to 20° to the east of the main cloud. The area designated "N" was reported (by teletypewriter) as an area of strong radar echoes by a Navy reconnaissance plane. The area marked "17" includes the cloud mass of figure 4. The area marked "18" includes the cloud mass to the west of the main cloud in figure 5 (bottom mosaic). See text. (b) A single frame from (a). Compare the marked spiral cloud organization to the north of the main cloud mass, with the weak organization in figure 1. The long east-west cloud structure labeled "A" is assumed to be related to the ITC. The cloud marked "B" illustrates the thin cloud lines oriented perpendicular to the cloud streets.

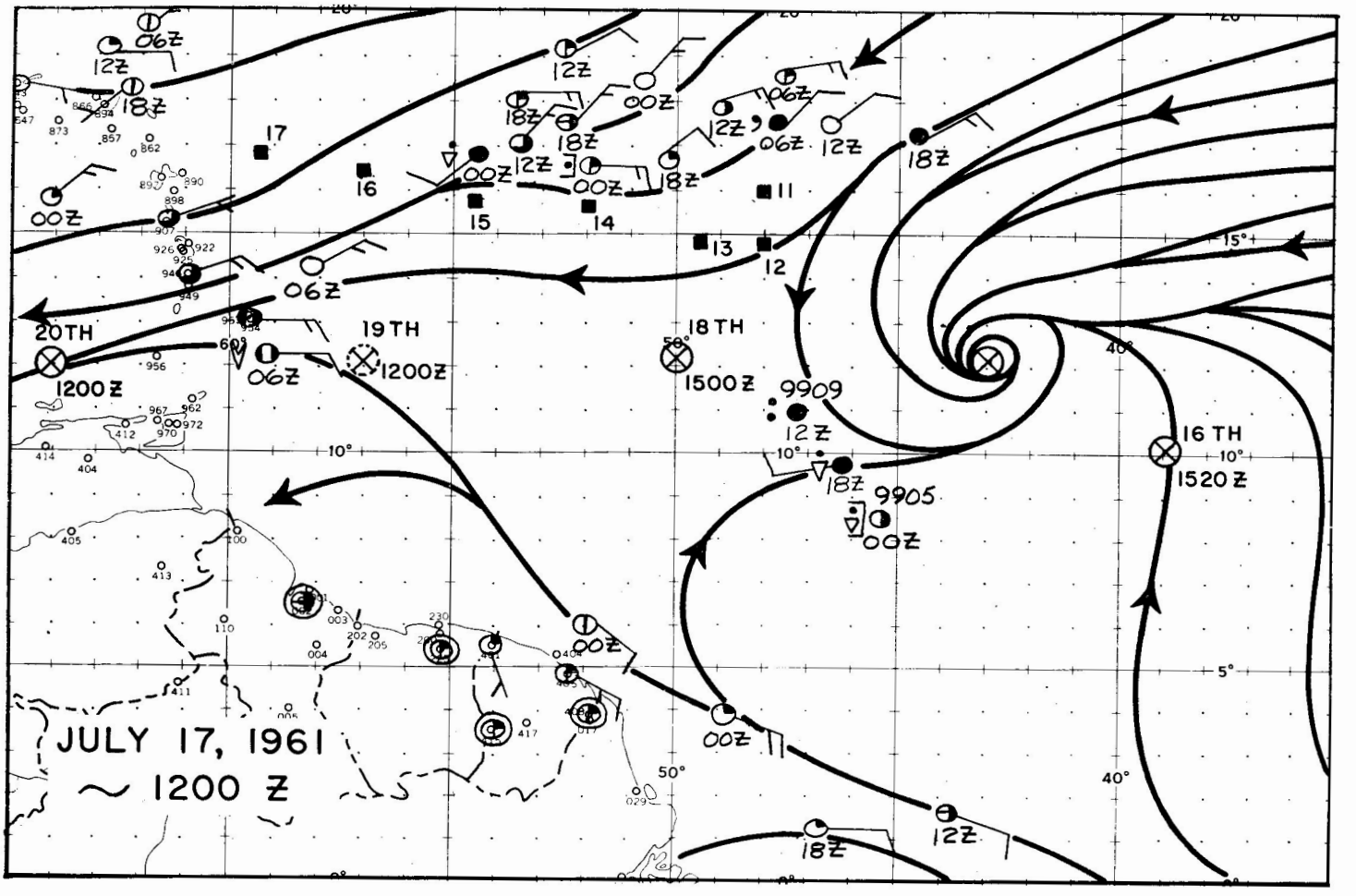



FIGURE 3.—A streamline analysis based on all available ship reports (0600 GMT, July 17 through 0000 GMT, July 18) and the satellite pictures in figures 2 and 4, as well as on continuity from previous days. The streamlines in the northern part of the tropical cyclone have been drawn nearly parallel to the cloud streets in figure 2b. The symbol ⊗ indicates a position near the middle of the large cloud masses in figures 1, 2, and 5 at the times indicated; the position at 1200 GMT, July 19 is interpolated. The symbol ■ indicates the Navy reconnaissance plane at various weather reporting positions. (Although "99" is not a permissible code figure for wind direction, the reports 9909 and 9905 near 10° N., 45° W. may have been an attempt to indicate rapidly variable wind direction, since in the ship's weather log the remark "wind turned" was entered at the 1200 GMT, July 17 observation, and in the same observation the waves were coded as "49" which means "confused, direction indeterminate." The entries 9909 and 9905, although transmitted by teletypewriter, were crossed out on the log; however the remark and the wave coding were allowed to stand.)

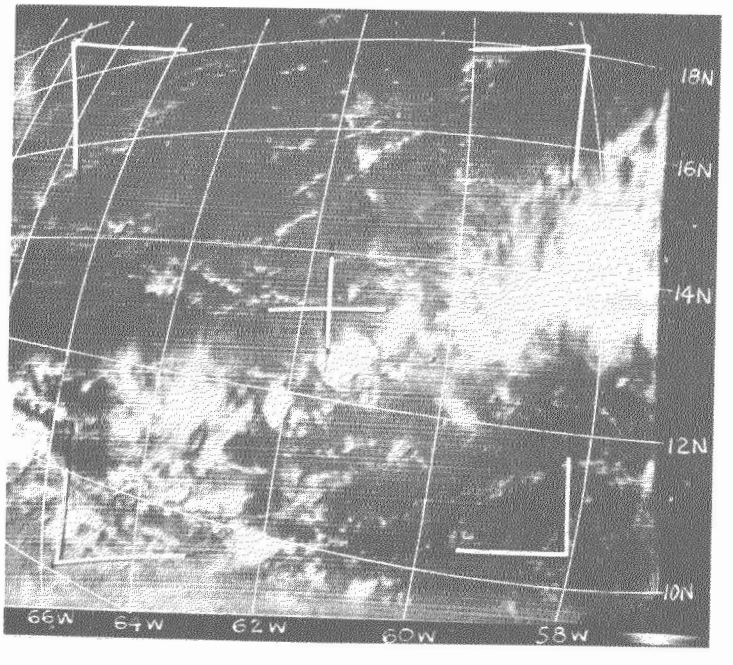



FIGURE 4.—A picture made by TIROS III at about 1630 GMT, July 17, 1961, on which a latitude-longitude grid has been superimposed. The Windward Islands lie north-south near longitude 61° W.

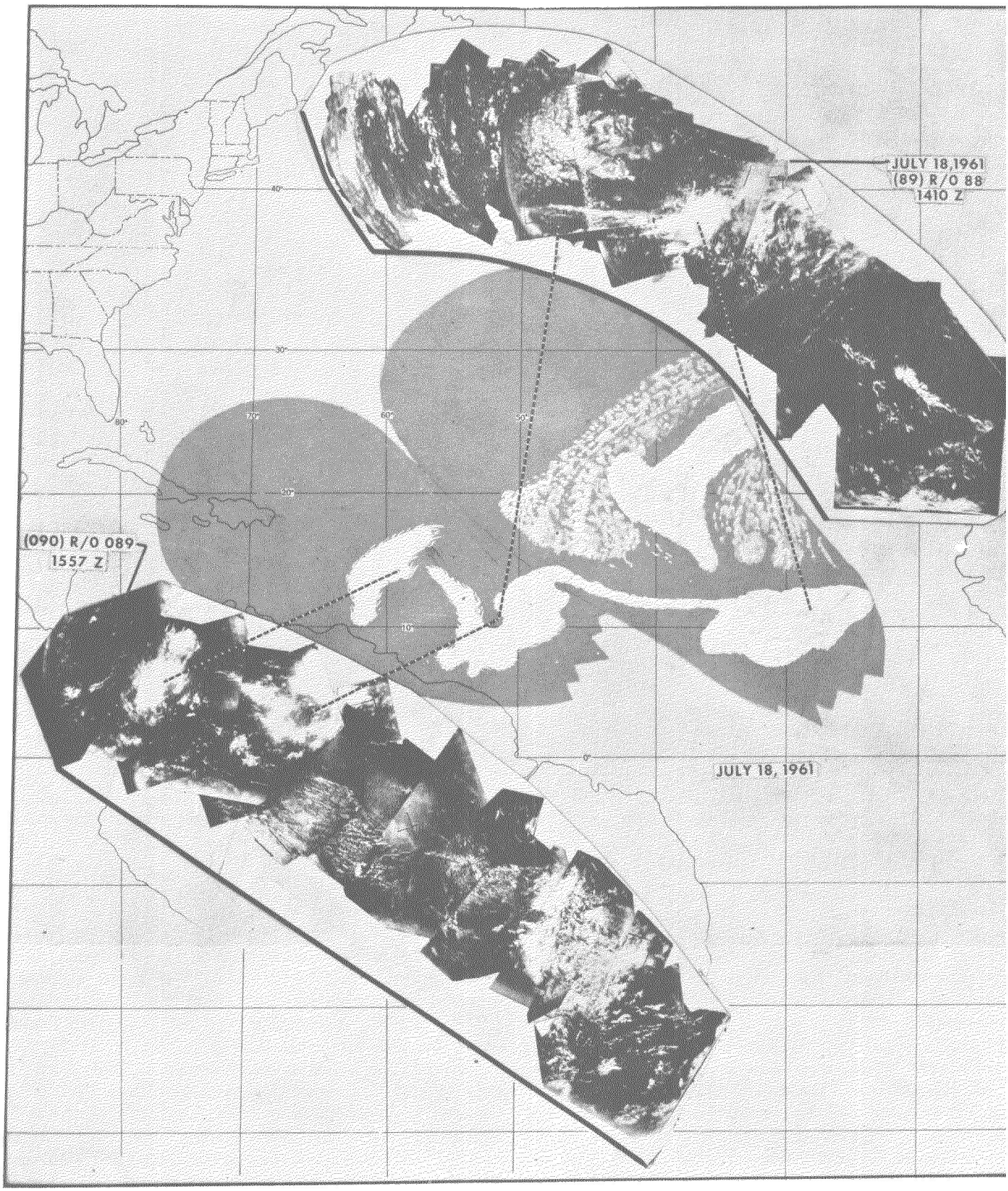



FIGURE 5.—Two composites from TIROS III made on successive passes. The main cloud mass which appeared in figures 1 and 2 is here located very close to the satellite's horizon in the upper composite. The western part of that cloud mass is more clearly seen in the bottom mosaic, since the satellite was more nearly above the cyclone area. Note again the large cloudless areas, which include the northern coast of South America. The large cloud, which trails the main cloud, is again evident to the east. The isolated cloud, to the west of the main cloud (in the lower mosaic), lies northeast to southwest centered at about 16° N., 61° W. (see fig. 2a).

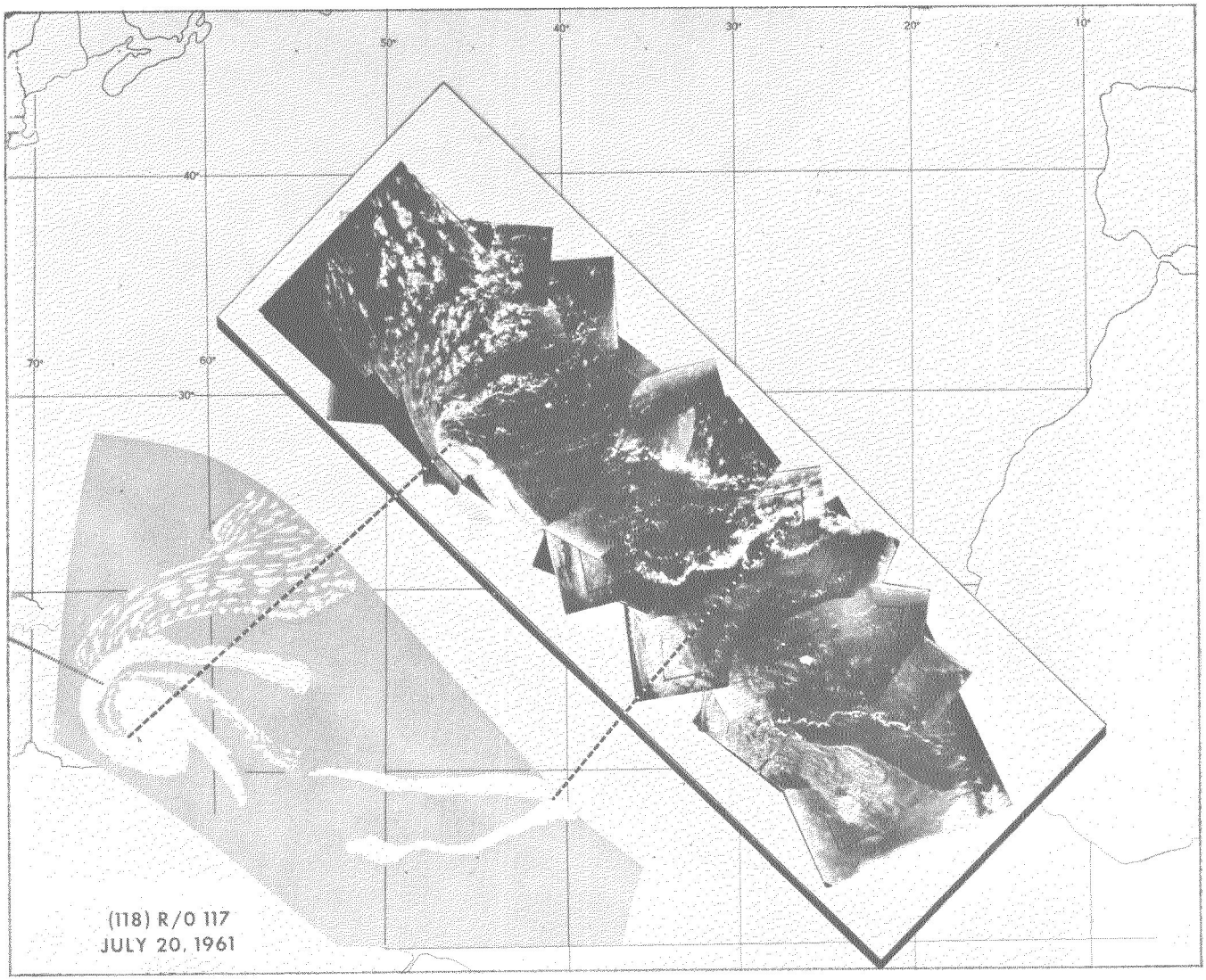



FIGURE 6.—A composite of pictures photographed by TIROS III on July 20, 1961. Hurricane Anna is located not far from the satellite's horizon. The spiralling array of the clouds to the north of the storm center is still evident. Note again the large cloudless areas to the south and east of the storm.

Moreover on July 18, the separated cloud mass was already west and north of the Windward Islands (fig. 2). Thus, it is not likely that this was the cloud system in which Anna developed to the east of the Windward Islands on July 19.

Returning to the tropical disturbance itself, there were, unfortunately, no pictures taken in the area on July 19, but on July 20, when the storm had reached hurricane force, TIROS produced the photographs in figure 6. This figure contains the hurricane cloud and shows the spiral organizations of the cumuliform cloud bands. The storm center was then located near 12° N., 64° W. [7, 8], representing a movement, along latitude 12° N., of about 7° of longitude per day. Since the cyclone was at 12° N., 50° W. at 1500 GMT July 18, such a movement would have placed the vortex near 12° N., 57° W. at 1200 GMT on July 19 (see fig. 3), and near 12° N., 61° W. at 0000 GMT on July 20. These positions of the cyclone agree well with the reported weather in the Windward Islands [8] which showed that "At 191200Z the vessel Bennekon reported easterly winds of 20 knots and 7-foot seas near 15° N., 55° W. About this time the Windward Islands began to show abnormal falls in pressure. At 200000Z the wind at Barbados had increased to 25 knots from 110 degrees, while St. Lucia reported 25 knots from 050 degrees. Coupled with considerable shower activity in the area, indications were that the easterly wave [or *tropical cyclone?* [5]] had passed Barbados and intensified. Intensification was confirmed when Grenada at 200500Z reported heavy squalls with gusts to 45 knots and 1002 mb. pressure."

[5] The words tropical cyclone have been inserted; the Fleet Weather Facility assumed that an easterly wave had passed Barbados.

## 2. SOME FEATURES IN THE CLOUD PICTURES

Several points of interest may be mentioned with regard to figures 2 and 5. A long, double-structured line of clouds stretched eastward from the spiral cloud area along latitude 12° N. on both July 17 and 18; this line of clouds is labeled "A" in figure 2b.

A cloud, with a similar appearance, was present near 14° N., 23° W. in a TIROS picture taken on July 15; on that day, a few ship reports plus the reports from the Cape Verde Islands showed that the line of clouds was in the area of convergence between winds from the northeast on the one hand, and winds from the southeast and southwest on the other hand. Thus, this cloud line was assumed to represent the intertropical convergence zone (ITC); we have therefore assumed also that the cloud line on July 17 represents the ITC and have drawn the analysis (fig. 3) accordingly. No counterpart of the ITC appears in the cloud system to the west of the cyclone center on July 16, 17, or 18.

Another point of interest in figure 2b appears on the cloud streets just north of the assumed "ITC cloud." Short, thin cloud lines appear more or less perpendicular to these cloud streets and are spaced at intervals along the cloud streets. An example of such a cloud array is shown at "B" in figure 2b. One may perhaps speculate that these represent cumuliform clouds with sufficient vertical development so that they have arrived at an elevation where the wind direction is different from the lower-level wind direction. If so, these short, thin cloud lines would represent clouds which have been sheared off the tops of the cumuliform clouds, which are themselves arrayed along the cloud streets.

Still other marked features are the large dark, cloudless areas which appear in all the mosaics, especially to the south of the "ITC cloud." These cloudless regions doubtless represent areas of widespread low-level divergence, a fact which can be used in synoptic analysis (fig. 3).

[6] See footnote 1, p. 507.

## 3. CONCLUSION

It is evident from the material presented that hurricane Anna was already a tropical cyclone [6] on July 17, well out in the Atlantic and far from reporting ships. In the absence of satellite data, the storm was first considered to have a "circulation" on July 18 or 19 [2, 8] or even as late as July 20 [7]; and this circulation was supposed to have started near the Windward Islands. Therefore, this study raises the question as to whether or not many of the hurricanes traditionally assumed to have originated near the Antilles, did in fact already exist as tropical cyclones in the Atlantic, long before they reached the Caribbean area. It will be interesting to study the origin of hurricanes in the future when more satellite observations will be available.

## ACKNOWLEDGMENT

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